

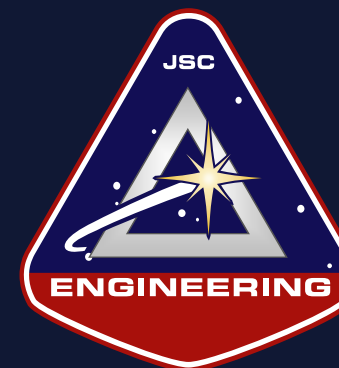


Johnson Space Center Engineering Directorate  
L-8: Using Human-Machine Interactions to Enhance Astronaut  
Performance and Adaptation in Reduced Gravity Environments

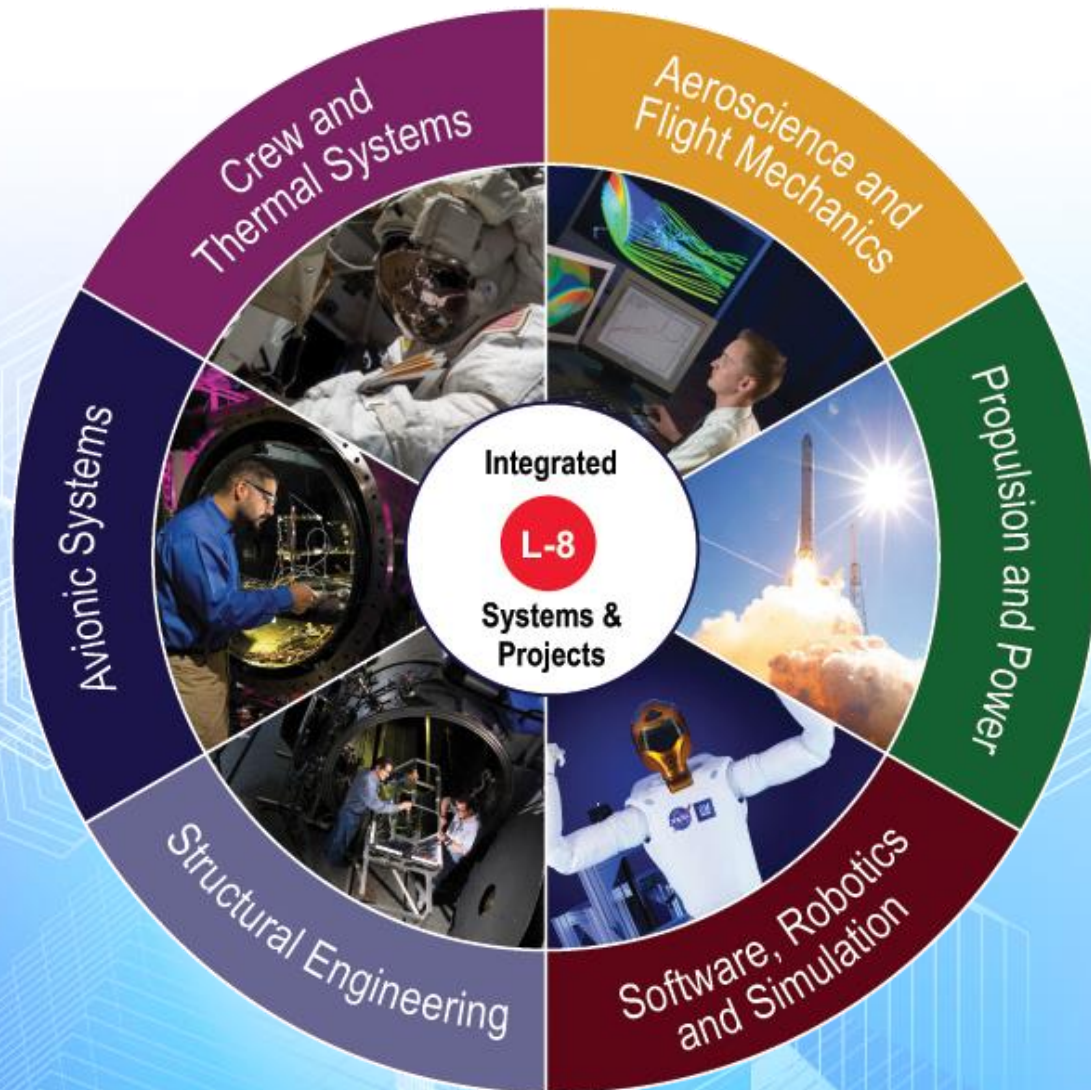
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Cody Burkhart  
November 2016



# JSC Engineering: HSF Exploration Systems Development



- We are sharpening our focus on Human Space Flight (HSF) Exploration Beyond Low Earth Orbit
- We want to ensure that HSF technologies are ready to take Humans to Mars in the 2030s.
  - Various Roadmaps define the needed technologies
  - We are attempting to define our activities and dependencies
- Our Goal: Get within 8 years of launching humans to Mars (L-8) by 2025
  - Develop and Mature the technologies and systems needed
  - Develop and Mature the personnel needed
- We need collaborators to make it happen, and we think they can benefit by working with us.



# EA Domain Implementation Plan Overview

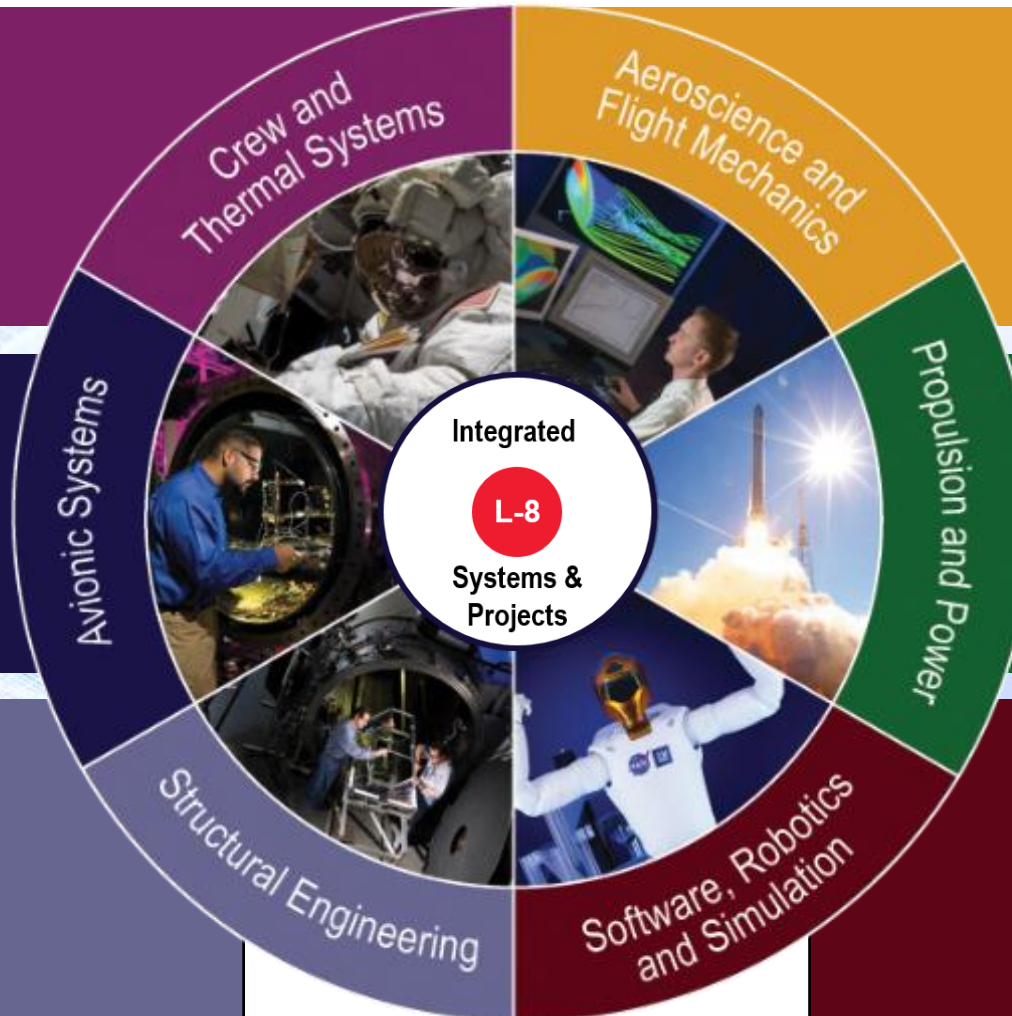
JSC Engineering: HSF Exploration Systems Development



- Life Support
- Active Thermal Control
- EVA
- Habitation Systems

- Human System Interfaces
- Wireless & Communication Systems
- Command & Data Handling
- Radiation & EEE Parts

- Lightweight Habitable Spacecraft
- Entry, Descent, & Landing
- Autonomous Rendezvous & Docking
- Vehicle Environments



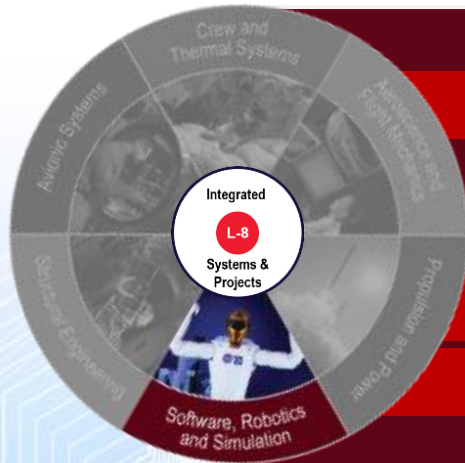
- Entry, Descent, & Landing
- Autonomous Rendezvous & Docking
- Deep Space GN&C

- Reliable Pyrotechnics
- Integrated Propulsion, Power, & ISRU
- Energy Storage & Distribution
- Breakthrough Power & Propulsion

- Crew Exercise
- Simulation
- Autonomy
- Software
- Robotics

AA-2 | iPAS | HESTIA | Morpheus

# Software, Robotics, & Simulation



- Crew Exercise
- Simulation
- Autonomy
- Software
- Robotics

## The Problem

### **What is the current state of the art?**

- Large, mechanically driven hardware with low data collection capability that requires multiple hardware elements to support crew health

### **What is the problem we are solving?**

- New vehicles designed for deep space, and wide-spread commercial use applications, require a massively more compact unit, rooted in robotics and data collection, that provides a human-machine interface that creates individualized programming in any environment on Earth or in space

### **Why do we want to do this?**

- A sensor enhanced, human-machine exercise unit provides crew, ground rehabilitation centers, and human performance groups with an unprecedented, individualized and intelligent system to customize for specific health and performance needs

## Using Human-Machine Exercise Systems to Enhance Astronaut Performance and Adaptation in Reduced Gravity Environments

### **What are we proposing?**

- We seek to develop a compact, sensor rich, robotics/motor driven system that enhances both muscular and cardiovascular crew needs with additions of sensorimotor development that provides the crew with engineering and physiological feedback

### **What is our idea?**

- Building a motor-based exercise unit that can be programmed with machine learning to individualize and tailor exercise protocols to users to promote increased health and performance outcomes in a small, reliable and robust unit

### **What is the benefit to a collaborator both in space and commercially?**

- Currently there is no high-fidelity unit capable of meeting the needs of crew support for our efforts to reach Mars and beyond; the same unit required for this effort provides immense opportunity for success in rehabilitation clinics and athlete development arenas given the user-centric, individualized nature of the system

### **What kind of collaboration do we envision?**

- While our end-game is physiological improvement and sustainability, we see the symbiotic relationships of software developers, learning language applications, sensor experts, electronics/power/motor groups, and robotics, among many other disciplines, to support a human-centric methodology

### **What kind of partner do we want to grow with?**

- We want a partner who understands that no matter the landscape, deep space or ground based, that the human comes before all else





# MOTOR SKILL

***USING HUMAN-MACHINE EXERCISE SYSTEMS TO  
ENHANCE ASTRONAUT PERFORMANCE AND  
ADAPTATION IN REDUCED GRAVITY ENVIRONMENTS***

CODY BURKHART . NASA-JSC . ARED PM

The image shows a gold-colored, dome-shaped exercise device labeled 'MED 2.0' on its side. It is connected to a tablet displaying a control interface with various metrics. The device is mounted on a black perforated metal plate. A blue pedal and a blue handle are also visible, connected to the device. The background is a light-colored wooden surface.

# MED-2

(Miniature Exercise Device)





# ORIGINS

***"EVERY NEW BEGINNING COMES FROM SOME OTHER  
BEGINNING'S END."***

***-SENECA***



An aerial photograph of a city, likely Houston, Texas, showing a dense urban landscape with a grid-like street pattern, green spaces, and a large body of water (the Houston Ship Channel) on the right side. A semi-transparent dark rectangle is overlaid in the center, containing white text.

# JOHNSON SPACE CENTER

Center for Human Spaceflight





# PHYSIOLOGY IMPACTS

Consequences of Zero-G  
Environments

20kV

X100 100µm



## EXPOSURES

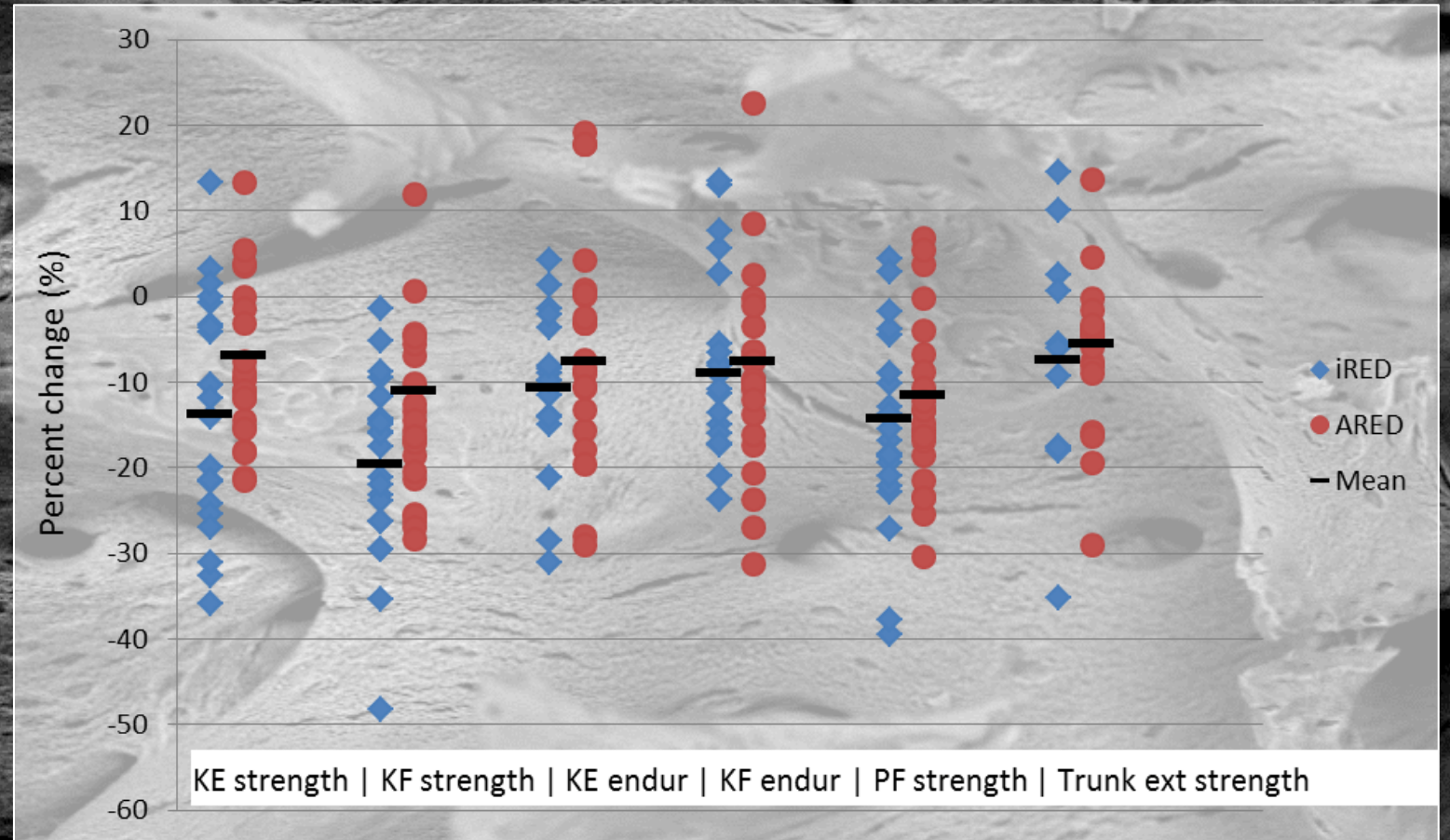
LAUNCH & LANDING  
LOADS

MICROGRAVITY

CLOSED  
ENVIRONMENT  
(AIR AND WATER)

CONFINED HABITAT

RADIATION  
EXPOSURE



20kV

X100 100µm



# HUMAN RESPONSE TO SPACEFLIGHT

## CARDIOVASCULAR

*14% ISS crew experiencing aerobic capacity loss greater than permissible loss limit*

## MUSCULAR

*25% ISS crew experiencing muscle loss beyond permissible loss limit*

## SKELETAL

*Risk of fracture due to decline of bone/mass strength may not be reversible after return to earth.  
1-2% loss per month without mitigations; ~ 0.5% loss per month with mitigations*

## NUEROVESTIBULAR / SENSORIMOTOR

*88% of crew can't walk upon landing*

## BEHAVIORAL

## NUTRITIONAL

## IMMUNOLOGICAL

1G AVG: -22%, SHUTTLE 9-14 DAY MISSION LOSS  
AVG: -17%, ISS 15-DAY MEASURE  
AVG: -15%, ISS POST-FLIGHT MEASURE

**VO<sub>2</sub>MAX**

AVG: -7.4%, SHUTTLE 17-DAY MISSION LOSS  
AVG: -12.1%, NASA/MIR 4-7 MO. LOSS

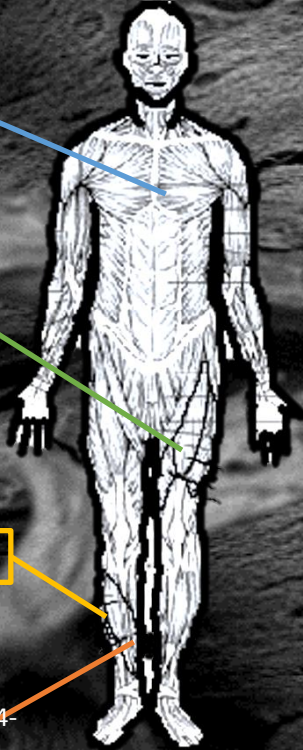
**QUADRICEPS**

AVG: -12.4%, SHUTTLE 17-DAY MISSION LOSS  
AVG: -23.8%, NASA/MIR 4-7 MO. LOSS

**GASTROCNEMIUS**

AVG: -9.8%, SHUTTLE 17-DAY MISSION LOSS  
AVG: -19.6%, NASA/MIR 4-7 MO. LOSS

**SOLEUS**



20kV

X100 100µm





# EVOLUTION

***"THE WORLD WILL NOT EVOLVE PAST ITS CURRENT  
STATE OF CRISIS BY USING THE SAME THINKING THAT  
CREATED THE SITUATION."***

***– ALBERT EINSTEIN***



A man in a grey t-shirt and black shorts is performing a squat on the ARED machine. He is holding a horizontal bar with both hands, and his feet are on a platform. The machine is blue and silver, with a monitor and various sensors. The background is a blue curtain.

# ARED

## Advanced Resistive Exercise Device



A woman with dark curly hair, wearing a blue athletic top and shorts, is running on a treadmill inside a space station. She is wearing a white safety harness and a watch. The treadmill is mounted on a blue frame. The background shows the interior of the space station with various equipment and structural elements.

# COLBERT (T2)

Combined Operational Load-  
Bearing External Resistance  
Treadmill





# CEVIS

Cycle Ergometer with  
Vibration Isolation &  
Stabilization





# HISTORICAL LESSONS

Apex Predators only stay at  
the top if they are adaptive





# DATA MINING

***"ANYTIME SCIENTISTS DISAGREE, IT'S BECAUSE WE  
HAVE INSUFFICIENT DATA."***

***–NEIL DEGRASSETYSON***



A photograph of several smartwatches with different colored straps (red, black, gold) displayed in a glass case on a wooden surface. The watches are arranged in a row, and their reflections are visible on the glass. In the background, blurred figures of people are visible, suggesting a retail or exhibition environment.

# ACTIVITY TRACKING

No longer just metrics for the  
coach & the devout





# INTEGRATION

**Embedded technology to show  
what has otherwise been  
unseen**





# TRAJECTORY

***IF YOU HAVE BUILT CASTLES IN THE AIR, YOUR WORK  
NEED NOT BE LOST; THIS IS WHERE THEY SHOULD BE.  
NOW PUT THE FOUNDATIONS UNDER THEM.***

***– HENRY DAVID THOREAU***





# NEXT GEN

Compact, Integrated Human-  
Machines





# **PAYDIRT**

**Recovery needs to be  
accelerated when every  
minute counts**





# EXECUTE

***A GOOD PLAN VIOLENTLY EXECUTED RIGHT NOW IS FAR  
BETTER THAN A PERFECT PLAN EXECUTED NEXT WEEK.***

***– GEORGE S. PATTON***



A dramatic photograph of a rocket launch. The rocket is positioned vertically in the center, ascending into a dark sky. A massive, bright orange and yellow plume of smoke and fire erupts from the base, filling the lower half of the frame. To the left, a tall, white service tower with a lattice structure is visible, extending upwards. In the bottom right corner, parts of launch pad infrastructure, including railings and a building, are visible. The overall scene is one of intense power and technological achievement.

# COMMERCIAL SPACE FLIGHT

The number of bodies in space  
is about to take-off



A full-page background image showing a NASA astronaut in a white spacesuit with an American flag patch on the sleeve, shaking hands with a humanoid robot. The robot has a gold-colored head and torso with blue and red lights. The astronaut's suit also features a NASA logo and a GM logo. The background is a deep blue, suggesting outer space.

# PARTNERSHIP

Success is dependent on  
prioritization of the human  
above all else



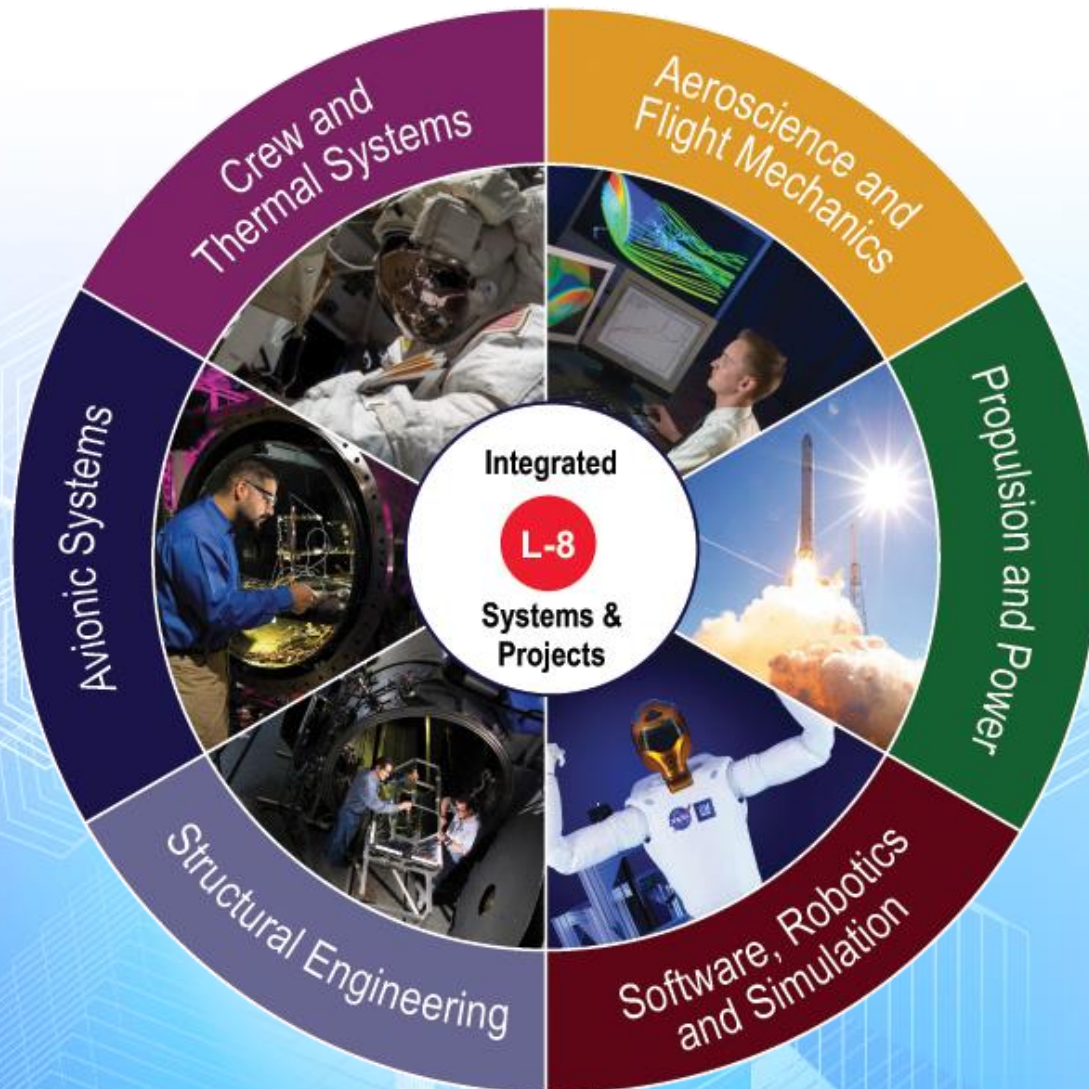


# EYES WIDE

**“The most beautiful experience we can have is the mysterious. It is the fundamental emotion that stands at the cradle of true art and true science. Whoever does not know it and can no longer wonder, no longer marvel, is as good as dead, and his eyes are dimmed.”**



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  - [Pointer to Co-Dev Announcements](#)
  - [Pointer to intake site](#)